Claims

What is claimed is:

1. A method for diagnosing the possibility of disease in a body part, the method comprising

measuring electrical data of the body part with a plurality of N_e electrodes;

representing the body part by a network, said network having external nodes corresponding to the location of the plurality of the N_e electrodes and internal nodes, wherein the internal and external nodes are connected by current pathways;

determining electrical properties associated with the pathways using the measured electrical data; and

utilizing the electrical properties to diagnose the possibility of disease in the body part.

2. The method of claim 1, wherein the step of measuring includes measuring an impedance z_{ij} of the body part.

3. The method of claim 2, wherein the step of measuring an impedance z_{ij} of the body part includes

injecting a current i_i between an i^{th} electrode chosen from among the plurality and a base electrode taken to be the N_e^{th} electrode of the plurality;

measuring a resultant voltage V_{ij} between a j^{th} electrode chosen from among the plurality and the base electrode; and

repeating the steps of injecting and measuring to calculate an $N_e - 1 \times N_e - 1$ impedance matrix Z_{N_B} with matrix elements z_{mn} given by $z_{mn} = V_{mn} / i_m$ where $1 \le i \le N_e - 1$ and $1 \le j \le N_e - 1$.

4. The method of claim 3, wherein the step of determining electrical properties associated with the pathways includes calculating an $N_e \times N_e$ admittance matrix Y_{N_B} from the impedance matrix Z_{N_B}.

5. The method of claim 4, wherein the step of determining electrical properties associated with the pathways further includes determining a conductance matrix, G, for the body part by using the admittance matrix Y_{N_B}.

6. The method of claim 5, wherein the step of utilizing the electrical properties includes

obtaining a typical conductance matrix from a population group; and

comparing the conductance matrix for the body part and the typical conductance matrix from a population group to diagnose the possibility of disease in the body part.

7. The method of claim 5, wherein the step of utilizing the electrical properties includes

determining a conductance matrix for a homologous body part; and

comparing the conductance matrix for the body part and the conductance matrix for the homologous body part to diagnose the possibility of disease in the body part.

8. The method of claim 7, wherein the step of comparing includes displaying a first representation of the body part having current pathways with associated branch conductances and a second represention of the body part having current pathways with associated branch conductances.

9. The method of claim 5, wherein the step of determining a conductance matrix includes solving the equation

$$G_{ee} - G_{ei} G_{ii}^{-1} G_{ei}^{T} = \mathrm{Re}(Y_{N_B})$$

where, if N_e is the number of external nodes and N_i is the number of internal nodes, then G_{ee} is an $N_e \times N_e$ matrix, G_{ei} is an $N_e \times N_i$ matrix and G_{ii} is an $N_i \times N_i$ matrix defined by

$$G = \begin{pmatrix} G_{ee} & G_{ei} \\ G_{ei}^{T} & G_{ii} \end{pmatrix}.$$

10. The method of claim 9, wherein solving the equation includes utilizing at least one of Newton's method for a system of nonlinear equations and a continuation method.

11. The method of claim 5, wherein the step of measuring electrical data further includes calculating an average impedance matrix $\overline{Y}$, by averaging Y_{N_B} and a second admittance matrix $Y_{Z_{same}}$.

12. The method of claim 11, wherein the step of determining a conductance matrix includes solving the equation

$$G_{ee} - G_{ei}G_{ii}^{-1}G_{ei}^{T} = \mathrm{Re}(\overline{Y}),$$

where, if N_e is the number of external nodes and N_i is the number of internal nodes, then G_{ee} is an $N_e \times N_e$ matrix, G_{ei} is an $N_e \times N_i$ matrix and G_{ii} is an $N_i \times N_i$ matrix defined by

$$G = \begin{pmatrix} G_{ee} & G_{ei} \\ G_{ei}^{T} & G_{ii} \end{pmatrix}.$$

13. The method of claim 12, wherein solving the equation includes utilizing at least one of Newton's method for a system of nonlinear equations and a continuation method.

14. The method of claim 1, wherein the current pathways intersect only at external nodes or internal nodes.

15. The method of claim 1, wherein the current pathways are line segments of the network.

16. The method of claim 1, wherein the external nodes lie on a perimeter of the network and the internal nodes lie inside the perimeter.

17. The method of claim 1, wherein the step of determining electrical properties associated with the pathways includes determining a conductance matrix, G, for the body part by using at least one of an admittance matrix Y_{N_b} obtained from impedance measurements of the body part and an admittance matrix Y_{Zsame} obtained from tetrapolar impedance measurements of the body part.

18. The method of claim 1, wherein the electrical properties are elements of an admittance matrix Y, the step of determining including obtaining the admittance matrix by solving an admittance equation.

19. A system for diagnosing the possibility of disease in a body part, the system comprising

an electrode array for measuring electrical data of the body part, said electrode array having a plurality of N_e electrodes;

a network module for representing the body part by a network, said network having external nodes corresponding to the location of the plurality of the N_e electrodes and internal nodes, wherein the internal and external nodes are connected by current pathways;

an electrical properties module for determining electrical properties associated with the pathways using the measured electrical data; and

a diagnosis module for utilizing the electrical properties to diagnose the possibility of disease in the body part.

20. The system of claim 19, further comprising a multichannel impedance measuring instrument for obtaining an impedance z_{ij} of the body part.

21. The system of claim 20, wherein, after the electrode array is used to a) inject a current i_i between an i^{th} electrode chosen from among the plurality and a base electrode taken to be the N_e^{th} electrode of the plurality, and b) measure a resultant voltage V_{ij} between a j^{th} electrode chosen from among the plurality and the reference electrode, a multichannel impedance measuring instrument calculates z_{ij} according to $z_{ij} = V_{ij}/i_i$ where $1 \le i \le N_e - 1$ and $1 \le j \le N_e - 1$.

22. The system of claim 21, wherein, after steps a) and b) are repeated, the impedance module calculates an $N_e - 1 \times N_e - 1$ impedance matrix Z_{N_B} with matrix elements z_{mn} given by $z_{mn} = V_{mn}/i_m$ where $1 \le i \le N_e - 1$ and $1 \le j \le N_e - 1$.

23. The system of claim 22, wherein the electrical properties module includes an admittance module for calculating an $N_e \times N_e$ admittance matrix Y_{N_B} from the impedance matrix Z_{N_B}.

24. The system of claim 23 wherein the electrical properties module further includes a conductance calculator for determining a conductance matrix, G, for the body part by using the admittance matrix.

25. The system of claim 24, wherein the diagnosis module compares the conductance matrix for the body part to a typical conductance matrix from a population group to diagnose the possibility of disease in the body part.

26. The system of claim 24, wherein the diagnosis module compares the conductance matrix for the body part to a conductance matrix for a homologous body part to diagnose the possibility of disease in the body part.

27. The system of claim 24, wherein the conductance calculator solves the equation

$$G_{ee} - G_{ei}G_{ii}^{-1}G_{ei}^{T} = \mathrm{Re}(Y_{N_B}),$$

where, if N_e is the number of external nodes and N_i is the number of internal nodes, then G_{ee} is an $N_e \times N_e$ matrix, G_{ei} is an $N_e \times N_i$ matrix and G_{ii} is an $N_i \times N_i$ matrix defined by

$$G = \begin{pmatrix} G_{ee} & G_{ei} \\ G_{ei}^{T} & G_{ii} \end{pmatrix}.$$

28. The system of claim 27, wherein the conductance calculator solves the equation

$$G_{ee} - G_{ei}G_{ii}^{-1}G_{ei}^{T} = \mathrm{Re}(Y_{N_B})$$

by utilizing at least one of Newton's method for a system of nonlinear equations and a continuation method.

29. The system of claim 24, wherein the electrical properties module further includes an averaging module for calculating an average impedance matrix $\overline{Y}$, by averaging Y_{N_B} with a second admittance matrix.

30. The system of claim 29, wherein the conductance calculator solves the equation

$$G_{ee} - G_{ei}G_{ii}^{-1}G_{ei}^{T} = \mathrm{Re}(\overline{Y}),$$

where, if N_e is the number of external nodes and N_i is the number of internal nodes, then G_{ee} is an $N_e \times N_e$ matrix, G_{ei} is an $N_e \times N_i$ matrix and G_{ii} is an $N_i \times N_i$ matrix defined by

$$G = \begin{pmatrix} G_{ee} & G_{ei} \\ G_{ei}^{T} & G_{ii} \end{pmatrix}.$$

31. The system of claim 30, wherein the conductance calculator solves the equation

$$G_{ee} - G_{ei}G_{ii}^{-1}G_{ei}^{T} = \mathrm{Re}(\overline{Y})$$

by utilizing at least one of Newton's method for a system of nonlinear equations and a continuation method.

32. The system of claim 19, wherein the current pathways intersect only at external nodes or internal nodes.

33. The system of claim 19, wherein the current pathways are line segments of the network.

34. The system of claim 19, wherein the external nodes lie on a perimeter of the network and the internal nodes lie inside the perimeter.

35. The system of claim 19, further comprising at least one of an admittance module for obtaining an admittance matrix Y_{N_B} from impedance measurements of the body part and a Zsame module for obtaining an admittance matrix Y_{Zsame} from tetrapolar impedance measurements of the body part, the at least one the admittance matrix Y_{N_B} and the admittance matrix Y_{Zsame} used by the electrical properties module to obtain elements of a conductance matrix G as the electrical properties.

36. The system of claim 19, wherein the electrical properties are elements of an admittance matrix Y, the electrical properties module including an impedance calculator for obtaining the admittance matrix by solving an admittance equation.